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JET PROPULSION LABORATORY California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91109

Mail Station 183-501

25 February 1982

Refer to: 326-ABK:bg

Locke Stuart
Code 902.0
Goddard Space Flight Center
Greenbelt, MD 20771

Dear Locke:

As per our agreement, this letter constitutes the required reporting on the HCMM follow-on study, to date.

1. Twenty-six new images were requested in digital format. To date we have received 16 and have created logged-in images from these.

2. The problems with the field Thermal Inertia Meter have been identified, along with the modifications required to make this a truly usable field instrument. See attachment 1.

3. Algorithms for incorporating both atmospheric and elevation data simultaneously into the digital processing for creation of quantitatively correct thermal inertia images, are in the final development stage. See attachment 2.

4. Numerous new image products for geologic interpretation of both HCMM and aircraft thermal data have been produced. These include, among others, various combinations of the thermal data with Landsat and Seasat data. The combined data sets have been displayed using simple color composites, principal component color composites and black and white images, and hue, saturation intensity color composites. The effort here is directed toward showing specifically what new information is obtained by including the thermal data, over what can be obtained with the other data sets alone. Also HCMM color composites and HCMM-Landsat color composites are being prepared at the same scale as the $1^{\circ} \times 2^{\circ}$ geologic maps of the Mojave Desert area to facilitate field checking.

5. A field trip to Death Valley was undertaken in December to field check the aircraft and HCMM data reported on in the HCMM final report. Findings are currently being evaluated.

6. The <u>HCMM Anthology</u> was reviewed.

(E83-10036) [GEOLOGIC INTERPRETATION OF HCMM AND AIRCRAFT THERMAL DATA] (Jet Propulsion Lab.) 5 p HC A02/MF A01 CSCL 05B

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Future plans include:

1. Completion of the atmospheric-elevation correction to generate the best possible quantitative thermal inertia image for one scene, and evaluation of its probable numerical accuracy.

2. Complete the Death Valley interpretations.

3. Field work at Pisgah and other Mojave Desert areas.

4. Geologic interpretation of Pisgah and Mojave.

5. Final report.

Publications since May 1981 include:

Kahle, Anne B., John P. Schieldge, Michael J. Abrams and Ronald E. Alley, Some examples of the utility of HCMM data in geologic remote sensing, 1981 International Geoscience and remote Sensing Symposium (IGARSS '81) Digest, Volume II, pp 1183-1188, IEEE Geoscience and Remote Sensing Society, Washington, D.C., June 8-10, 1981.

Kahle, Anne B., John P. Schieldge, Michael J. Abrams, Ronald E. Alley and Catherine J. LeVine, Geologic application of thermal inertia imaging using HCMM data, HCMM Final Report, JPL Technical Report 81-55, 1981.

Marsh, Stuart E., John P. Schieldge and Anne B. Kahle, A simple instrument for measuring thermal inertia in the field, accepted, Photogrammetric Engineering and Remote Sensing, 1982.

Sincerely,

Anne B. Kahle

Anne B. Kahle
Supervisor, Geology Group

Enclosures

Attachment 1

In Situ Measurments of Thermal Inertia

Frank D. Palluconi

Remote thermal sensing of terrestrial surfaces provides a means of determining the surface thermal inertia. Thermal inertia is a composite surface property dependent on the conductivity, K, specific heat, c, and density, ρ, of the surface material. The interpretation of thermal images depends on being able to connect these derived thermal properties with the material responsible. Laboratory measurements of K, c, and ρ provide some guidance, but are generally inadequate for estimating the thermophysical properties of complex heterogeneous real surfaces. For this task an in situ technique is preferable.

Such a technique has been implemented at the Jet Propulsion Laboratory and is discussed extensively in "Geologic Application of Thermal Inertia Imaging Using HCMM Data," (JPL Publication 81-55, 1981). The method used introduces a short pulse (4 minutes) of energy into two standards (K, ρ, c known from laboratory measurement) and a sample (unknown thermal inertia P) and uses measurement of the temperature increase at the end of this heating to determine the thermal inertia of the sample. In application it was noticed that the derived thermal inertia for the sample showed a systematic dependence on which standard (Sand or Dolomite) was used as the reference. An attempt has been made to understand and remove the sources of this systematic difference.

Investigation revealed three sources of error:

1. Timing. The low inertia sand standard cools quickly. It is difficult in reading a meter by eye, to correctly assess the peak temperature at the end of heating. Using rapid (0.3s) digital recording at the end of the heating period eleminates this problem and indicated the maximum temperature of the sand may have been underestimated by as much as 1K.

2. Brightness temperature. The surface temperature of the standards and sample are measured using a radiometer operating in the 8 to 14 μm region. The quartz sand used as a standard has a much lower emissivity in the 8 to 10 μm region than the dolomite standard. This combined with the higher final temperature of the quartz leads to a 2K differential error between the quartz and the dolomite.

3. Non-uniform heating across the standards and sample. Two dimensional infrared images of the heated standards revealed a pattern of non-uniform heating from the lamp reflector combination. Since the conductivity of the dolomite is more than an order of magnitude larger than that of the sand, lateral heat conduction in the dolomite is significant. This results in a larger final temperature for the dolomite.

The three sources of error outlined above can either be eliminated through improvements in instrumentation or design (1. & 3.) or accounted for in the computation (2.). In addition, it is possible that coating both the standards and sample with a thin (10-100 μm) layer of high emissivity material (e.g. lampblack) could remove any remaining uncertainty due to differences in emissivity and absorbtance.

Investigating and identifying the sources of systematic error in this in situ measurement technique has greatly increase confidence that high accuracy field measurements of thermal inertia can be made.

Attachment 2

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HCMM FOLLOW-ON STUDY QUARTERLY REPORT: ATMOSPHERIC CORRECTION

WE ARE USING THE COMPUTER CODE LOWTRAN 5 TO DETERMINE THE ATMOSPHERIC CONTRIBUTION TO THE RADIANCE MEASURED BY THE HCMR. ALTHOUGH THE LOWTRAN DOCUMENTATION INCLUDES GENERAL COMMENTS REGARDING THE VALIDITY OF THE CALCULATIONS, WE HAVE UNDERTAKEN AN EVALUATION OF THE PROCEDURE TO ALLOW ESTIMATION OF POSSIBLE ERRORS IN THE 10 TO 12 MICRON REGION. SUPPORT FOR THE EVALUATION PROCESS HAS BEEN PROVIDED BY THE SMIRR EXPERIMENT AS WELL AS BY THE HCMM FOLLOW-ON STUDY. ACTIVITY SPECIFIC TO THE HCMM TASK INCLUDES THE DEVELOPMENT OF AN ALGORITHM WHICH EXPRESSES THE ATMOSPHERIC EFFECTS AS A CORRECTION TO THE BRIGHTNESS TEMPERATURE. INCORPORATION OF THIS PROCEDURE INTO OUR CURRENT EXISTING THERMAL INERTIA MODEL HAS BEEN INITIATED.

END OF DATA